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Alcohol Use and Firearm Violence

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Although the misuse of firearms is necessary to the occurrence of firearm violence, there are other contributing factors beyond simply firearms themselves that might also be modified to prevent firearm violence. Alcohol is one such key modifiable factor. To explore this, we undertook a 40-year (1975–2014) systematic literature review with meta-analysis. One large group of studies showed that over one third of firearm violence decedents had acutely consumed alcohol and over one fourth had heavily consumed alcohol prior to their deaths. Another large group of studies showed that alcohol was significantly associated with firearm use as a suicide means. Two controlled studies showed that gun injury after drinking, especially heavy drinking, was statistically significant among self-inflicted firearm injury victims. A small group of studies investigated the intersection of alcohol and firearms laws and alcohol outlets and firearm violence. One of these controlled studies found that off-premise outlets selling take-out alcohol were significantly associated with firearm assault. Additional controlled, population-level risk factor and intervention studies, including randomized trials of which only 1 was identified, are needed. Policies that rezone off-premise alcohol outlets, proscribe blood alcohol levels and enhance penalties for carrying or using firearms while intoxicated, and consider prior drunk driving convictions as a more precise criterion for disqualifying persons from the purchase or possession of firearms deserve further study.

alcohol; firearm; gun ownership; gun possession; homicide; injury; suicide

INTRODUCTION

Strategies to prevent firearm violence that focus only on the firearms themselves, as a modifiable target for intervention, are often delayed because of political and implementation challenges (1, 2). Although the misuse of firearms is necessary to the occurrence of firearm violence, there also are other contributing but modifiable factors that might be more feasibly changed to prevent firearm violence (3, 4).

Alcohol is one such key modifiable factor that has been repeatedly connected to firearm violence. People may place themselves or others at risk of gun violence by inappropriately consuming alcohol in situations where firearms are present. People may also place themselves or others at risk of gun violence by entering environments where alcohol is being consumed and where guns are present (3, 4). Moreover, exposure to both inappropriate alcohol consumption and gun use may, at times, be unavoidable or unbeknownst to those at risk because of ambient structural or circumstantial conditions, such as addiction or poverty.

Despite these possibilities, it is also possible that alcohol may not be as strongly related to firearm violence as expected. In the United States, a majority of the population does *not* abstain from alcohol consumption and, by extension, there are a great many instances of drinking where no firearm violence occurs. According to the 2013 US National Survey on Drug Use and Health (NSDUH), around 71% of adults aged 18 years or older drank alcohol in the prior year and around 56% in the prior month (5). Also, although alcohol could be a relatively straightforward factor to modify compared with firearm use, doing so may only be complementary to more direct efforts focused on firearm use, and modifying alcohol misuse as a behavior also has its own implementation challenges. Even with significant investments in prevention and treatment efforts, a nontrivial number of people (7.2% of adults aged 18 years or older in the United States in 2012) continue to suffer from alcohol addictions or alcohol use disorders (6).

Alcohol consumption is thus best viewed as a contributing, although not necessary, factor in the occurrence of firearm violence. The scientific evidence base focused on alcohol and firearm violence has yet to be fully audited in disentangling and determining the strength of this connection, as well as the importance of alcohol, as a modifiable risk factor in

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the prevention of firearm misuse and injury. Because this scientific evidence base has not heretofore been assembled, changes to alcohol policies in order to prevent firearm violence have been very limited. Communities interested in pursuing alcohol-related prevention strategies to reduce firearm violence are left with little guidance in terms of which strategies might be best to implement. We thus undertook a systematic review and meta-analysis of the scientific literature in order to synthesize the existing evidence base on alcohol and firearm violence. We identified gaps in knowledge, sought to elucidate modifiable factors or public health interventions, and offer information of value to local communities in making the best use of limited resources in pursuing alcohol policies and prevention strategies with robust evidence behind them.

METHODS

A systematic literature review with meta-analysis investigating the relationship between alcohol and firearms was completed for the 40 years from 1975 through 2014. Although a larger scientific literature exists investigating the alcohol-violence connection and the alcohol-suicide connection, this review was restricted to the alcohol-firearm injury connection. In this regard, a subset of articles was identified that focused on the alcohol-firearms connection. The remaining larger balance of articles that were identified focused primarily on alcohol and violence or alcohol and suicide, but they were included only if they were part of the alcohol and firearms subset.

Three literature search engines were used: PubMed, Web of Science, and Scopus. Standard, reproducible Boolean search algorithms were submitted to each of these 3 literature search engines. In PubMed, article title, abstract, and keywords were searched by using the following Boolean algorithm: ("firearm" [MeSH Terms] OR "firearm" [All Fields] OR "gun" [All Fields]) AND ("ethanol" [MeSH Terms] OR "ethanol" [All Fields] OR "alcohol" [MeSH Terms] OR "alcohol" [All Fields] OR "alcohol outlet" [All Fields]), where MeSH is Medical Subject Heading. This initially produced 438 articles. In Web of Science, article title, abstract, and keywords were searched by using the following Boolean algorithm: ("firearm" OR "gun") AND ("ethanol" OR "alcohol" OR "alcohol outlet"), initially producing 321 articles. In Scopus, the Boolean algorithm ("firearm" OR "gun") AND ("ethanol" OR "alcohol" OR "alcohol outlet") was used for article title, abstract, and keywords, initially producing 629 articles.

Among these 1,388 articles in total, non-human-based or forensic/other technical studies and non-English-written studies were excluded first. Then non-original research articles such as reviews, meta-analyses, and editorials (except those by Smith et al. (7) and Kuhns et al. (8)) were excluded. The articles that remained at this point were then reconciled for duplicates. Further exclusions were then applied: studies of violence, homicide, or suicide in general that did not specifically report data for firearm violence, firearm homicide, or firearm suicide; studies of substance use that did not specifically report alcohol use; studies that did not specify guns or firearms, but instead only broadly specified "weapons"; forensic science case-series prior to 1995 (these case-series had already been comprehensively reviewed and summarized in meta-analyses by Smith et al. (7) and Kuhns et al. (8) which were abstracted for their relevant data); smaller studies restricted to special populations (murder-suicides, schizophrenics, police officers, physicians, individuals in active war or conflict situations); and studies that did not address the relationship between firearms and alcohol. Four studies that had been cited as reporting a relationship between alcohol and firearms but that were not found as part of our search strategy were also found and included in our final analyses. These 4 studies were found in the reference lists of the articles identified in our search strategy, not by the search strategy itself. Figure 1 depicts the flow-chart showing the inclusion and exclusion of our studies. The final yield of studies investigating the relationship between alcohol and firearms from all 3 search engines was 51 total articles (93 total individual articles when counting the meta-analyses by Smith et al. (7) and Kuhns et al. (8)).

These 51 articles were then separated and analyzed in multiple categories based on data source (countries, measure) and study population demographics (age, sex). Systematic reviews and meta-analytical summaries were reported in 4 categories: 1) alcohol use and firearm injury victimization, 2) alcohol use and firearm use, 3) alcohol sales outlets and firearm injury victimization, and 4) alcohol laws and firearm use in the United States.

Two types of summary estimates were calculated, where possible. The first type of summary estimate was overall prev-alence estimates using study-population weighted means and weighted standard deviations. These overall prevalence esti-mates included tables reporting the prevalence of acute alco-hol use among firearm injury deaths and the prevalence of firearm use among alcohol users. A second group of calcu-lated summary estimates were overall summary odds ratios obtained by using the Stata 13 (StataCorp LP, College Sta-tion, Texas) command, *metan*. These overall odds ratios were weighted by using study population sizes. Overall sum-mary odds ratios were calculated only for the relationship between any alcohol use and firearm possession and for the relationship between heavy alcohol use and firearm suicides. Heavy alcohol use was defined when named as such in a study (i.e., "heavy alcohol use") or by blood alcohol concen-tration, "binge drinking," "alcohol dependence," or "alcohol problems."

A third part of our analysis reviewed studies reporting relationships between proximity to alcohol outlets and firearm injury, but without meta-estimation given the limited number of data points. In addition, we also reported state laws restrict-ing sales, possession, or use of firearms by alcohol users.

RESULTS

Alcohol use and firearm injury victimization

A prior meta-analysis of articles from 1975 to 1995 by Smith et al. (7) identified 18 articles that specifically addressed alcohol consumption and firearm injury. All these articles were decedent case-series drawn mostly from published coroner and medical examiner studies, as well as some hospital-based studies. One of the articles in this prior meta-analysis reported on unintentional firearm injury, 9 on firearm homicide, and 8

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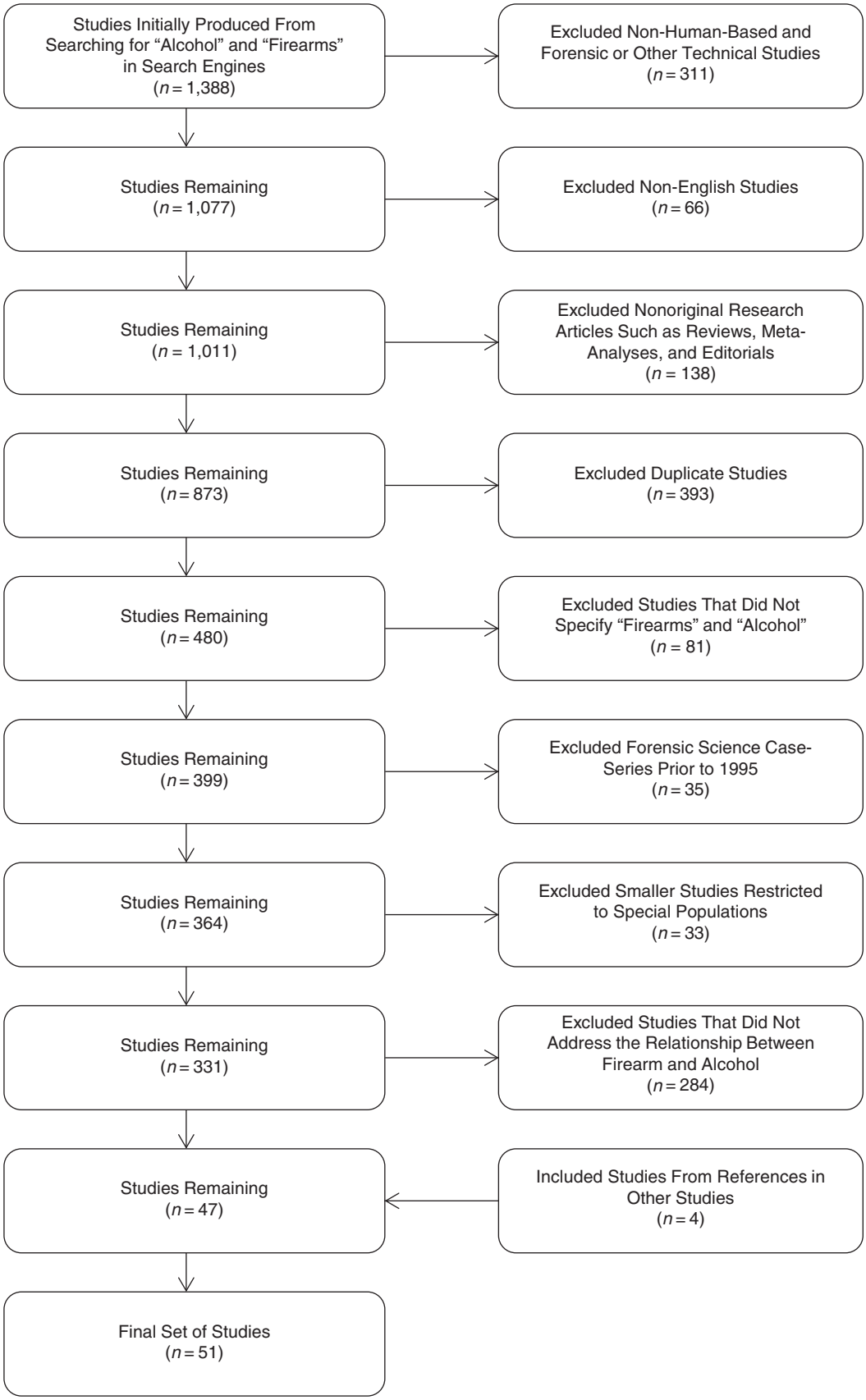

Figure 1. Selection process for research articles on alcohol use and firearm violence, 1975–2014.

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Table 1. Articles Reporting Prevalence of Acute Alcohol Use Among Firearm Injury Decedents

First Author, Year (Reference No.)	Study Population	No.	Location	Data Source	Any Alcohol Use, %	Heavy Alcohol Use, %	Study Population-Weighted Mean (SD), %
			Firearm Homicide				
Smith, 1999 (7)	Decedents	6,145	United States	Meta-analysis	38.9	30.6	Any alcohol use = 37.2 (7.4), heavy alcohol use = 30.1 (4.4)[a]
Branas, 2009 (3)	Decedents	126	Philadelphia, Pennsylvania		24.5	8.2	
Johnson, 2000 (46)	Decedents	387	Alaska		14.3	NA	
Armour, 1996 (47)	Decedents	103	United Kingdom		39.4	NA	
Andreuccetti, 2009 (48)	Decedents	1,605	Brazil		40.1	NA	
Darke, 2008 (49)	Decedents	128	Australia		37.5	NA	
Ehmke, 2014 (50)	Decedents	1,455	South Africa		41.0	NA	
Fedakar, 2007 (51)	Decedents	3,463	Turkey		8.1	NA	
Hougen, 2000 (52)	Decedents	83	Norway/Denmark		25.3	12.0	
Moug, 2001 (53)	Decedents	51	United Kingdom		64.0	44.0	
Rainio, 2005 (54)	Decedents	348	Finland		50.0	30.6	
Rancic, 2013 (55)	Decedents	120	Serbia		25.0	NA	
			Firearm Suicide				
Smith, 1999 (7)	Decedents	601	United States	Meta-analysis	33.1	31.4	Any alcohol use = 35.0 (1.0), heavy alcohol use = 25.2 (1.1)[a]
Branas, 2011 (4)	Decedents	137	Philadelphia, Pennsylvania		31.0	19.9	
Conner, 2014 (56)	Decedents	19,621	United States	NVDRS	35.0	NA	
Johnson, 2000 (46)	Decedents	387	Alaska		27.1	NA	
Kaplan, 2009 (57)	Decedents	11,554	United States	NVDRS	NA	27.3	
Kaplan, 2013 (58)	Decedents	29,198	United States	NVDRS	NA	24.8	
Shields, 2006 (59)	Decedents	1,932	Kentucky		37.9	NA	
Kohlmeier, 2001 (60)	Decedents	1,704	Bexar, Texas		31.9	25.5	
Giesbrecht, 2015 (18)	Decedents	51,547	United States	NVDRS	35.1	24.8	
Aşirdizer, 2010 (61)	Decedents	73	Turkey		17.8	NA	
Blumenthal, 2007 (62)	Decedents	406	South Africa		40.0	36.0	
Ehmke, 2014 (50)	Decedents	1,455	South Africa		42.0	NA	
Fedakar, 2007 (51)	Decedents	3,463	Turkey		3.7	NA	
Lester, 2012 (63)	Decedents	787	Australia		43.6	NA	
Moug, 2001 (53)	Decedents	17	United Kingdom		41.7	25.0	
Rainio, 2005 (54)	Decedents	348	Finland		57.7	41.6	
Sutton, 2005 (64)	Decedents	38	United Kingdom		42.1	26.3	
Schmeling, 2001 (65)	Decedents	19	Germany		31.6	NA	
			Firearm Accident				
Smith, 1999 (7)	Decedents	54	United States	Meta-analysis	48.7	20.5	
			Firearm Death (Homicide, Suicide, and Accident Combined)				
Galea, 2002 (66)	Decedents	11,133	New York, New York		26.9	NA	
Al Madni, 2008 (67)	Decedents	64	Saudi Arabia		1.6	NA	
Myint, 2014 (68)	Decedents	149	Thailand		31.1	NA	
Paniagua, 2005 (69)	Decedents	789	El Salvador		22.0	NA	

Abbreviations: NA, not available; NVDRS, National Violent Death Reporting System; SD, standard deviation.
[a] The population-weighted means are for all "Firearm Homicide" and "Firearm Suicide" studies, respectively, not just for the single paper of Smith (7).

on firearm suicide. To these articles was added a list of 27 decedent case-series articles addressing alcohol consumption and firearm injury, published after 1995.

Table 1 lists 45 articles reporting prevalences of acute alcohol use among firearm injury decedents. Each article contains a case-series of firearm injury decedents and their levels of alcohol consumption estimated from blood specimens as blood-alcohol concentrations (in mg/dL). Blood-alcohol concentrations >0 mg/dL indicated "any alcohol use," and blood-alcohol concentrations >80 mg/dL or comparable

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Table 2. Articles Reporting Odds Ratios Between Acute Alcohol Use and Firearm Injury

First Author, Year (Reference No.)	Study Population	No.	Location	Data Source	Type of Alcohol Use	Alcohol Use and Firearm Injury	
						Odds Ratio	95% Confidence Interval
Firearm Assault							
Branas, 2009 (3)	Adults	1,361	Philadelphia, Pennsylvania	Case-control study	Any alcohol use	1.3	0.5, 3.3
Branas, 2009 (3)	Adults	1,361	Philadelphia, Pennsylvania	Case-control study	Heavy alcohol use	2.7	0.9, 7.9
Firearm Homicide							
Branas, 2009 (3)	Adults	251	Philadelphia, Pennsylvania	Case-control study	Any alcohol use	0.3	0.1, 3.1
Branas, 2009 (3)	Adults	251	Philadelphia, Pennsylvania	Case-control study	Heavy alcohol use	6.2	0.4, 92.5
Firearm Self-Inflicted Injury							
Branas, 2011 (4)	Adults	451	Philadelphia, Pennsylvania	Case-control study	Any alcohol use	4.2[a]	2.3, 8.0
Branas, 2011 (4)	Adults	451	Philadelphia, Pennsylvania	Case-control study	Heavy alcohol use	77.1[a]	8.8, 678.4
Firearm Suicide							
Branas, 2011 (4)	Adults	411	Philadelphia, Pennsylvania	Case-control study	Any alcohol use	5.9[a]	2.9, 12.1
Branas, 2011 (4)	Adults	411	Philadelphia, Pennsylvania	Case-control study	Heavy alcohol use	85.8[a]	10.0, 732.3

[a] Statistically significant, $P < 0.05$.

amount indicated "heavy alcohol use" (heavy alcohol use being a subset of any alcohol use).

Among the 45 studies included, 26 studies used US-based data, while the remaining 10 used non-US data. Given the heterogeneity between different national populations, only the prevalence of alcohol use among firearm injury deaths for the United States was summarized. A weighted mean of 37.2% of US firearm homicide decedents had acutely consumed any alcohol prior to their death (population-weighted standard deviation, 7.4%). A weighted mean of 30.1% of US firearm homicide decedents had acutely consumed a heavy amount of alcohol prior to their death (population-weighted standard deviation, 4.4%). A weighted mean of 35.0% of US firearm suicide decedents had acutely consumed any alcohol prior to their death (population-weighted standard deviation, 1.0%). A weighted mean of 25.2% of US firearm suicide decedents had acutely consumed a heavy amount of alcohol prior to their death (population-weighted standard deviation, 1.1%). Articles published after 1995 reported similar levels of alcohol involvement among firearm injury decedents as the prior 20-year meta-analysis by Smith et al. (7) and 1 other prior literature review (9), suggesting consistency of these percentages over time.

Two case-control studies, shown in Table 2, have begun to address the many analytical shortcomings emerging from the 45 prior case-series studies by calculating and reporting odds ratio estimates of the relationship between acute alcohol consumption and subsequent firearm injury victimization. Both case-control studies incorporate fatal and nonfatal case groups alongside population-based, community controls (3, 4). Alcohol consumption in both studies was measured by using blood specimens, police reports, and participant self-reports. The odds ratio of being a victim of gun injury after acute alcohol use appears to be most pronounced, and statisti-cally significant, among self-inflicted firearm injury victims (including completed suicides).

Table 2 also indicates that these odds ratios differ somewhat according to alcohol consumption levels and type of shooting. Individuals who consumed any amount of alcohol experienced about the same odds ratios of being shot by others as nondrinkers. However, individuals who consumed any amount of alcohol were significantly, from 4 to 6 times, more likely to shoot themselves or to commit suicide with a gun than nondrinkers. The odds ratios for self-inflicted firearm injuries among heavy alcohol users were also noticeably large and statistically significant, being more than 14 times that of the odds ratios for any alcohol users.

Alcohol use and firearm use

The only randomized controlled trial found in our search was by Carr et al. (10), and it investigated alcohol use and the ability to use a firearm. Adult male participants who were nonhabitual drinkers with no professional firearms training were enrolled in this trial and randomly assigned to receive alcohol (titrated to 0.05 or 0.10 g/100 mL) or placebo alcohol. All participants were then subjected to 160 real-world, large screen video-immersion scenarios using a high-fidelity deadly force judgment and decision-making simulator with real, untethered firearms that had been retrofitted to fire "laser bullets" and simulate real firearm recoil and noise. These same simulators are used by many law enforcement and military agencies for training and testing. This study found that, after alcohol consumption, intoxicated subjects demonstrated slower reaction times in scenarios not requiring judgment (0.87 seconds for the first shot and 1.49 seconds for the first hit) and faster reaction times (5.22 seconds for the first shot and 4.41 seconds for the first hit) and less accuracy (−0.47%) in scenarios requiring complex decision making before deciding to use force. The study placebo alcohol group experienced modest reductions in reaction times and no decrease in accuracy.

Table 3 lists 8 articles representing 33 total studies (when adding in the 26 studies from Kuhns et al. (8)). These articles show the prevalence of alcohol use (both any alcohol use and

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Table 3. Articles Reporting Prevalence of Alcohol Use Among Firearm Users

First Author, Year (Reference No.)	Study Population	No.	Location	Data Source	Type of Firearm Use	Type of Alcohol Use	Alcohol Use Among Firearm Users, %
			Firearm Possession				
Black, 1994 (70)	Adolescent boys (9–15 years of age)	192	United States	Surveys	Gun carrying	Any alcohol use	36.0
Carter, 2013 (71)	Youth (14–24 years of age)	689	Flint, Michigan	Hospital records	Gun possession	Heavy alcohol use (binge drinking)	39.6
Johnson, 2012 (72)	Adult women using out-of-treatment substance	858	St. Louis, Missouri	Interviews	Gun carrying	Heavy alcohol use (alcohol dependence)	60.0
Greenfeld, 2001 (11)	Crime offenders	1,982,552	United States	NCVS	Gun possession	Any alcohol use	15.6
Kuhns, 2014 (8)	Homicide offenders	28,265	United States and 8 countries	Meta-analysis	Gun use	Any alcohol use	34.0
Junuzovic, 2013 (12)	Hunters	1,000	Sweden		Gun use	Any alcohol use	1.0
			Firearm Ownership				
Wintemute, 2011 (15)	Adults	15,474	United States	BRFSS	Gun ownership	Any alcohol use	59.3
Hemenway, 1997 (73)	Adults	800	United States	National survey	Gun ownership	Heavy alcohol use (binge drinking)	20.0

Abbreviations: BRFSS, Behavioral Risk Factor Surveillance System; NCVS, National Crime Victimization Survey.

heavy alcohol use) among firearm users (both firearm possession and firearm ownership). These studies represented a variety of countries and study populations prohibiting the calculation of a meaningful summary statistic. The prevalence of alcohol use among individuals who possessed firearms ranged from 1% among a cohort of hunters in Sweden to 60% in a group of adult women with a substance abuse history in the United States. In 2 studies, more than one third of adolescents and youth in possession of guns were also reportedly drinking alcohol or heavily drinking alcohol. By comparison, among adults who owned firearms, almost 60% consumed some amount of alcohol, and 20% consumed alcohol heavily. Only 3 articles (8, 11, 12) reported percent estimates of the consumption of alcohol at the time of firearm use, and these percentages ranged from 1.0% to 34.0%. Two of these 3 articles analyzed large cohorts of criminal offenders. The remaining articles reported time-independent estimates of the relationship between alcohol and firearm use.

Table 4 lists articles reporting the prevalence of firearm use (both firearm possession and firearm ownership) among alcohol users (both any alcohol use and heavy alcohol use). On average, just over one fourth (26.5%; range, 17.4%–65.7%) of adolescents with any alcohol use also had carried guns. About 5% of adolescents whose drinking onset age was before 13 years of age had carried guns. Although these studies document important information about the nontrivial levels of alcohol involvement among firearm users, especially adolescents, they are limited by cross-sectional study designs and absence of comparison groups.

Tables 5 and 6 list articles reporting odds ratio estimates of the association between alcohol use and firearm use. The definitions of alcohol use were based on self-reports and coroner/medical examiner reports, and they ranged from any alcohol use to heavy alcohol use including binge drinking and alcohol dependence. Firearm use (both firearm possession and firearm ownership) was also based on self-reports and coroner/medical examiner reports.

Table 5 shows 10 studies reporting odds ratio estimates between alcohol use (any alcohol use and heavy alcohol use) and firearm use (firearm possession and ownership), except for the study by Stevens et al. (13) that reports relative risk ratios. All studies used US-based data sets except for the study by Erickson et al. (14) that collected data internationally. Overall, in the United States, adolescents showed higher odds ratios between alcohol use and firearm use than adults did. For the relationship between any alcohol use and firearm possession, the reported odds ratio point estimations for adolescents in 5 studies ranged from 1.8 to 4.6, all of which were higher than that for adults, 1.3, reported in the study by Wintemute (15). Also, the odds ratio estimates between heavy alcohol use and firearm possession were higher for adolescents, 1.8 from Loh et al. (16), than for adults, 1.5, taken from both Nelson et al. (17) and Wintemute (15). Two studies, Wintemute (15) and Nelson et al. (17), reported odds ratios between alcohol use and firearm ownership. Both studies used US adult data from the Behavioral Risk Factor Surveillance System (BRFSS) surveys. The odds ratios reported in these studies ranged from 1.3 to 1.8 and were consistently statistically significant.

For the 5 reported adolescents' odds ratios between any alcohol use and firearm possession, Figures 2 and 3 provide meta-analysis summary statistics and corresponding forest plots. The summary estimates in these figures were weighted by the

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Table 4. Articles Reporting Prevalence of Firearm Use Among Alcohol Users

First Author, Year (Reference No.)	Study Population	No.	Location	Data Source	Type of Firearm Use	Type of Alcohol Use	Firearm Use Among Alcohol Users, %	Study Population-Weighted Mean (SD), %
Firearm Possession								
Estell, 2003 (74)	Adolescents (10–15 years of age)	345	A southern state, United States	Survey	Gun carrying	Any alcohol use	65.7	26.5 (21.6)[a]
Simon, 1997 (75)	Adolescents (15–16 years of age)	504	California	Survey	Gun carrying	Any alcohol use	56.5	
Stevens, 2001 (13)	Adolescents (10–12 years of age)	3,145	Massachusetts, New Hampshire, Vermont	Survey	Gun possession	Any alcohol use	17.4	
Peleg-Oren, 2009 (76)	Adolescents (16–18 years of age)	1,726	Florida	YRBSS	Gun carrying	Drinking before age 13 years	12.0	4.6 (4.2)[a]
Peleg-Oren, 2009 (76)	Adolescents (16–18 years of age)	10,626	Florida	FYSAS	Gun carrying	Drinking before age 13 years	3.4	
Firearm Ownership								
Swahn, 2002 (77)	Adolescents (12–18 years of age)	18,454	United States	Youth Violence Survey	Gun easily available at home	Alcohol easily available at home	42.0	
Nordstrom, 2001 (78)	Adults	983	Iowa	Survey	Home with loaded, unlocked guns	Heavy alcohol use (alcohol dependence)	13.0	

Abbreviations: FYSAS, Florida Youth Substance Abuse Survey; SD, standard deviation; YRBSS, Youth Risk Behavior Surveillance System.
[a] The first population-weighted mean is for the 3 "Any alcohol use" studies of Estell (74), Simon (75), and Stevens (13); the second one is for the 2 "Drinking before age 13 years" studies of Peleg-Oren (76).

inverse of their study sample sizes. Figure 2 demonstrates that the overall odds ratio size across all the types of firearm pos-session was 2.64 (95% confidence interval: 1.99, 3.49) and statistically significant. In Figure 3, when restricted to only the 3 articles reporting gun carrying, the summary odds ratio remained roughly the same, 2.65 (95% confidence inter-val: 1.59, 4.44). Overall, these statistically significant odds ratio estimates demonstrated a positive association between alcohol use and firearm possession among adolescents in the United States.

Table 6 lists 4 studies that report odds ratio estimates between alcohol use and firearm suicide among US decedents. The odds ratio estimates in these studies represent the relationship between alcohol use (any alcohol use and heavy alcohol use) and firearms as a suicide means as compared with other suicide means. For any amount of alcohol, 2 studies reported odds ratios: 1 study (18) reported a relatively small but statistically significant odds ratio of 1.11, and the other study (19) reported an odds ratio of 1.68 that was not statistically significant. For heavy alcohol use, 3 studies reported 6 separate odds ratios, ranging from 0.81 to 1.76, broken down by sex and types of heavy alcohol use. Figure 4 shows meta-analysis summary statistics for these 6 odds ratios between heavy alco-hol use and firearm suicide means, using the inverse of study population sizes as weights to calculate a statistically signifi-cant summary odds ratio of 1.53 (95% confidence interval: 1.45, 1.60). These results suggest that heavy drinkers were significantly more likely to choose firearms over other suicide means, when compared with nondrinkers.

Alcohol sales outlets and firearm violence victimization

Individuals may place themselves at risk of firearm injury by consuming alcohol, but also possibly by entering into environments where alcohol is being consumed. One environmental approach to the control of injuries due to firearms may be to focus on point-of-sale alcohol outlets whose availability can vary greatly between different geographical areas. These alcohol outlets can typically be categorized as on-premise establishments, such as bars and taverns in which alcohol is both purchased and consumed, and off-premise establishments, such as takeouts and delis where alcohol is purchased but must be consumed elsewhere.

Despite a relatively large literature addressing the relationship between alcohol outlets and violence more broadly, only 3 studies (3, 4, 20) have specifically reported on the relationship between alcohol outlets and firearm violence, using US data. Relevant findings from these 3 studies are shown in Table 7 and demonstrate few strong or remarkable relationships. However, 1 study (3) did find that being in an area of high off-premise alcohol outlet availability significantly increased the odds ratio of falling victim to homicide assaults in an as-sault by 2.0 times. No significant results were found in the other 2 studies for other firearm-related outcomes.

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Table 5. Articles Reporting Odds Ratios Between Alcohol Use and Firearm Use

First Author, Year (Reference No.)	Study Population	No.	Location	Data Source	Type of Alcohol Use	Type of Firearm Use	Alcohol Use and Firearm Injury	
							Odds Ratio	95% Confidence Interval
Firearm Possession								
Erickson, 2006 (14)	Adolescent girls (14–17 years of age)	510	United States/ Netherlands/ Canada	Interviews	Heavy alcohol use	Threatened or tried to hurt with a gun	2.3	NA
DuRant, 1997 (79)	Adolescents (14–17 years of age)	3,054	Massachusetts	YRBSS	Any alcohol use	Gun carrying	1.8[a]	1.4, 2.3
DuRant, 1999 (80)	Adolescents (11–14 years of age)	2,227	North Carolina	YRBSS	Any alcohol use	Gun carrying	4.6[a]	1.3, 16.6
Loh, 2010 (16)	Adolescents (14–18 years of age)	3,050	Flint, Michigan	Hospital records	Any alcohol use	Gun access	3.4[a]	2.9, 4.0
Simon, 1997 (75)	Adolescents (15–16 years of age)	504	California	Survey	Any alcohol use	Gun carrying	2.5[a]	1.6, 4.2
Stevens, 2001 (13)	Adolescents (10–12 years of age)	3,145	Massachusetts, New Hampshire, Vermont	Survey	Any alcohol use	Gun use	2.1[a]	1.3, 3.3
Peleg-Oren, 2009 (76)	Adolescents (16–18 years of age)	12,352	Florida	YRBSS/ FYSAS	Drinking before age 13 years	Gun carrying	29.4[a]	6.6, 125.0
Loh, 2010 (16)	Adolescents (14–18 years of age)	3,050	Flint, Michigan	Hospital records	Heavy alcohol use (binge drinking)	Gun access	1.8[a]	1.4, 2.3
Wintemute, 2011 (15)	Adults	15,474	United States	BRFSS	Any alcohol use	Gun carrying	1.3	0.9, 1.8
Nelson, 1996 (17)	Adults	6,202	Oregon	BRFSS	Heavy alcohol use (binge drinking)	Gun carrying	1.5	0.9, 2.4
Wintemute, 2011 (15)	Adults	15,474	United States	BRFSS	Heavy alcohol use (binge drinking)	Gun carrying	1.5[a]	1.0, 2.1
Johnson, 2012 (72)	Adult women using out-of-treatment substance	858	St. Louis, Missouri	Interviews	Heavy alcohol use (alcohol dependence)	Gun carrying	1.3	0.9, 1.8
Firearm Ownership								
Wintemute, 2011 (15)	Adults	15,474	United States	BRFSS	Any alcohol use	Home with loaded, unlocked guns	1.4[a]	1.2, 1.7
Wintemute, 2011 (15)	Adults	15,474	United States	BRFSS	Any alcohol use	Gun ownership	1.3[a]	1.2, 1.5
Nelson, 1996 (17)	Adults	6,202	Oregon	BRFSS	Heavy alcohol use (binge drinking)	Home with loaded, unlocked guns	1.7[a]	1.3, 2.3
Wintemute, 2011 (15)	Adults	15,474	United States	BRFSS	Heavy alcohol use (binge drinking)	Home with loaded, unlocked guns	1.8[a]	1.5, 2.3
Wintemute, 2011 (15)	Adults	15,474	United States	BRFSS	Heavy alcohol use (binge drinking)	Gun ownership	1.3[a]	1.2, 1.5

Abbreviations: BRFSS, Behavioral Risk Factor Surveillance System; FYSAS, Florida Youth Substance Abuse Survey; NA, not available; YRBSS, Youth Risk Behavior Surveillance System.

[a] Statistically significant, $P < 0.05$.

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Table 6. Articles Reporting Odds Ratios Between Alcohol Use and Firearms Versus Other Suicide Means

First Author, Year (Reference No.)	Study Population	No.	Location	Data Source	Type of Alcohol Use	Alcohol Use and Firearm Injury	
						Odds Ratio	95% Confidence Interval
Giesbrecht, 2015 (18)	Suicide decedents	51,347	United States	NVDRS	Any alcohol use	1.11[a]	1.02, 1.20
Tewksbury, 2010 (19)	Suicide decedents	419	Jefferson, Kentucky	Coroner's report	Any alcohol use	1.68	0.95, 2.95
Giesbrecht, 2015 (18)	Suicide decedents	51,347	United States	NVDRS	Heavy alcohol use	1.59[a]	1.45, 1.75
Kaplan, 2009 (57)	Suicide decedents, male	10,615	United States	NVDRS	Heavy alcohol use (alcohol problem)	0.81[a]	0.73, 0.90
Kaplan, 2009 (57)	Suicide decedents, female	4,851	United States	NVDRS	Heavy alcohol use (alcohol problem)	0.97	0.80, 1,17
Kaplan, 2009 (57)	Suicide decedents, male	10,615	United States	NVDRS	Heavy alcohol use[a]	1.40	1.26, 1.55
Kaplan, 2013 (58)	Suicide decedents, male	45,386	United States	NVDRS	Heavy alcohol use[a]	1.76	1.61, 1.93
Kaplan, 2013 (58)	Suicide decedents, female	12,424	United States	NVDRS	Heavy alcohol use	1.68[a]	1.46, 1.93

Abbreviation: NVDRS, National Violent Death Reporting System.
[a] Statistically significant, $P < 0.05$.

Alcohol laws and firearm use in the United States

US federal law does not prohibit alcohol abusers from obtaining firearms (21). In light of this, 1 study (22) specifically reviewed state laws restricting the intersection of firearms and alcohol. The study's results are summarized in Table 8. As of 2008, a total of 46 laws in 31 states restricted the intersection of alcohol and firearms. More specifically, a total of 18 states categorically restricted firearm ownership or firearm use by individuals on the grounds of "habitual alcohol use." A total of 12 states had alcohol-specific firearm restrictions with respect to location, such as restricting possession of a loaded firearm in places where intoxicating liquor was sold. A total of 26 states had laws restricting firearms for people who were intoxicated: 6 states restricted the sale or transfer of firearms to an intoxicated person, 4 states restricted the carrying of a concealed weapon while intoxicated, and 20 states specifically restricted possession and/or discharge of a firearm by an intoxicated person.

DISCUSSION

A common and well-documented gun safety rule is "never use alcohol . . . before or while shooting" (23). Despite this, the current systematic review with meta-analysis suggests that a nontrivial proportion of firearm injury victims and

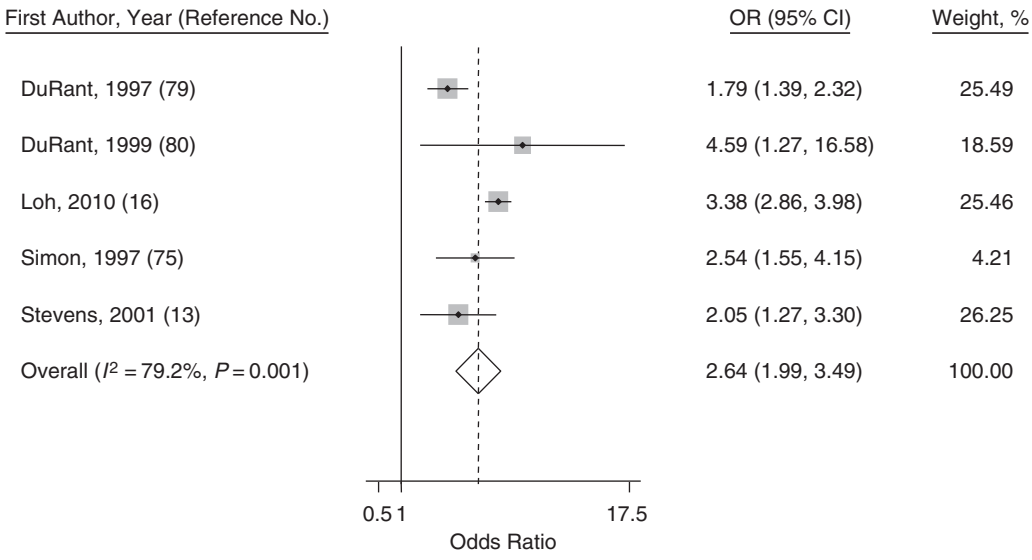

Figure 2. Meta-analysis odds ratios between any alcohol use and firearm possession for US adolescents. Refer to Table 5 for the details of each study's population, sample number, study location, data source, and type of firearm possession. The 5 studies were found to be heterogeneous (I^2 = 79.2%, P = 0.001). The summary estimate presented (diamond) was calculated by using study sample weights. Stevens et al. (13) report rel-ative risk instead of odds ratio. CI, confidence interval; OR, odds ratio.

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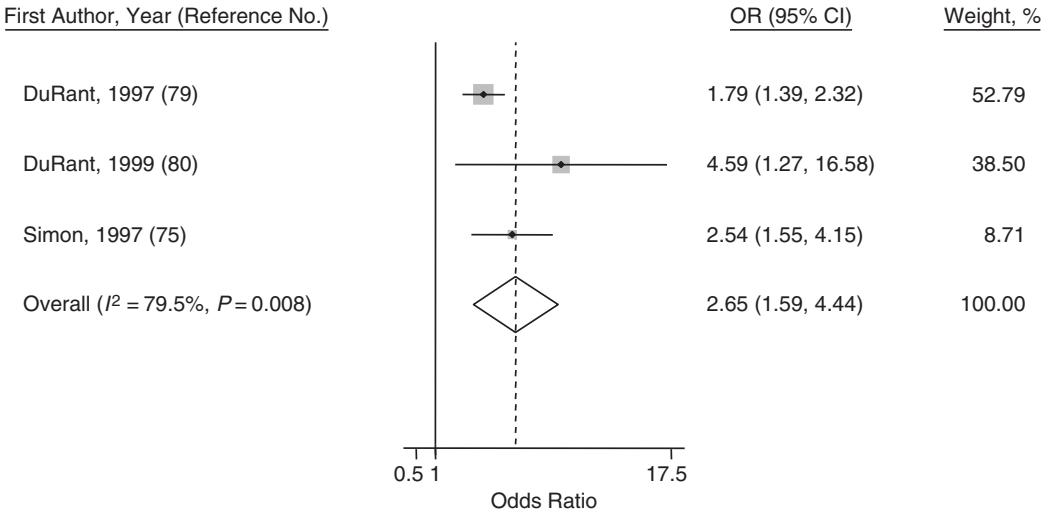

Figure 3. Meta-analysis odds ratios between any alcohol use and firearm carrying for US adolescents. Refer to Table 5 for the details of each study's population, sample number, study location, data source, and type of firearm possession. The 3 studies were found to be heterogeneous (I^2 = 79.5%, P = 0.008). The summary estimate presented (diamond) was calculated by using study sample weights. CI, confidence interval; OR, odds ratio.

firearm users concomitantly use or misuse alcohol. Forty years of peer-reviewed studies investigating the relationship between alcohol and firearm violence reveal a number of salient research findings, gaps in knowledge, and potential interventions worthy of further testing.

A large group of case-series studies showed that, on average, over one third of firearm injury decedents in the United States (homicides and suicides) had acutely consumed any amount of alcohol prior to their death and that over one fourth of these decedents had heavily consumed alcohol prior to their death. Despite being large in number, the summary statistics for these decedent case-series studies should not be overinterpreted. Because they were restricted only to individuals with firearm injuries (and even more so, fatal firearm injuries) with no control groups, these case-series studies offer little guidance in terms of the actual relationship that might exist between alcohol use and firearm injury, either from others or from oneself.

Only 2 analytical studies investigating the relationship between alcohol use and firearm injury were found. These 2 case-control studies demonstrated that the odds ratios of being a victim of gun injury after drinking, especially heavy

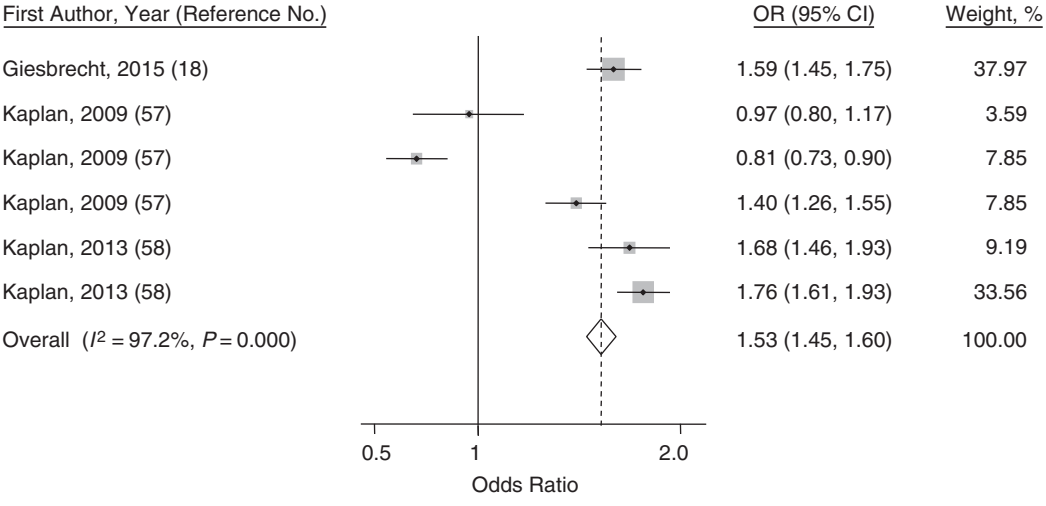

Figure 4. Meta-analysis odds ratios between heavy alcohol use and selection of firearms suicide means for US suicide decedents. Refer to Table 6 for the details of each study's population, sample number, study location, data source, and type of firearm possession. The 6 studies were found to be heterogeneous (I^2 = 97.2%, P = 0.000). The summary estimate presented (diamond) was calculated by using study sample weights. CI, confi-dence interval; OR, odds ratio.

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Table 7. Articles Reporting on the Relationship Between Alcohol Outlets and Firearm Injury

First Author, Year (Reference No.)	Type of Crime	Study Population	No.	Location	Data Source	Being Proximal to Alcohol Outlets		Being Proximal to On-Premise Alcohol Outlets		Being Proximal to Off-Premise Alcohol Outlets	
						OR	95% CI	OR	95% CI	OR	95% CI
Firearm Assault and Homicide											
Branas, 2009 (3)	Firearm assaults	Adult	1,361	Philadelphia, Pennsylvania	Case-control study	1.2	0.6, 2.5	1.1	0.6, 2.2	2.0[a]	1.1, 3.8
Branas, 2009 (3)	Firearm homicides	Adult	251	Philadelphia, Pennsylvania	Case-control study	0.7	0.2, 2.8	0.9	0.3, 2.7	4.2	0.8, 21.8
Schofield, 2013 (20)	Violent crime	New York State (except for New York City) counties	57	New York State	DCJS, census	NA	NA	4.8[b]	−3.2, 12.8	−4.5[b]	−13.3, 4.3
Self-Inflicted Firearm Injury and Firearm Suicide											
Branas, 2011 (4)	Self-inflicted gun injuries	Adult	451	Philadelphia, Pennsylvania	Case-control study	0.8	0.4, 1.3	0.8	0.4, 1.3	1.6	0.8, 2.9
Branas, 2011 (4)	Firearm suicides	Adult	411	Philadelphia, Pennsylvania	Case- control study	0.6	0.4, 1.1	0.6	0.4, 1.1	1.3	0.7, 2.6

Abbreviations: CI, confidence interval; DCJS, Division of Criminal Justice Services; NA, not applicable; OR, odds ratio.
[a] Statistically significant, $P < 0.05$.
[b] Value represents β, not odds ratio.

drinking, were most pronounced among self-inflicted and suicide firearm injury victims with statistically significant odds ratios of 4.0 or greater. Gun suicide victims often "brace" themselves with alcohol in anticipation of a painful or violent end (7, 24–26). Acute alcohol consumption, and perhaps heavy alcohol consumption, may make the impulsive and painful act of shooting oneself potentially easier and significantly more likely (4). Therefore, suppressing the availability of alcohol and guns during these times may be especially important from a public policy perspective (27). Nevertheless, 2 studies are not a sufficiently large number with which to generalize and form policy. The dearth of studies investigating firearm injury victimization after alcohol consumption remains a major gap in knowledge.

Studies of alcohol and firearm use, possession, or ownership were relatively plentiful when compared with studies of alcohol and firearm injury victimization. These studies consistently reported that alcohol use was significantly associated

Table 8. State Laws of the Intersection Between Alcohol and Firearms, 2008[a]

Law	States
Firearms Restrictions of Intoxicated Persons (n = 22 States)	
States restricting firearm possession and/or discharge of a firearm by intoxicated persons (at home or in public places)	Alaska, Colorado, Connecticut, Florida, Georgia, Maryland, Massachusetts, Michigan, Minnesota, Missouri, Nevada, New Mexico, Ohio, Oklahoma, Rhode Island, South Carolina, South Dakota, Tennessee, Texas, Utah
States restricting firearm sale or transfer to intoxicated persons	Alaska, Delaware, Indiana, Maryland, Tennessee, Texas
Firearms Restrictions of Habitual Alcohol Users (n = 22 States)	
States restricting firearm possession by alcohol addicts and/or habitual alcohol users (at home or in public places)	Alabama, Florida, Ohio
States restricting carrying concealed firearms by alcohol addicts and/or habitual alcohol users (in public places)	Colorado, Florida, Kentucky, Louisiana, Mississippi, Missouri, New Mexico, Wyoming
States restricting firearm sale, transfer, ownership, and/or licensure to alcohol addicts and/or habitual alcohol users	Alabama, Georgia, Hawaii, Indiana, Iowa, Maryland, Massachusetts, Nevada, New Jersey, Pennsylvania, Rhode Island, Tennessee, West Virginia
Firearms Restrictions of Intoxicating Liquor-Selling Locations (n = 12 States)	
States restricting possession of a loaded firearm in a place where intoxicating liquor is sold for on-premise consumption	Alaska, Arkansas, Illinois, Kentucky, Louisiana, Michigan, New Mexico, Oklahoma, South Carolina, Tennessee, Texas, Wisconsin
Firearms Restrictions of Other Alcohol-Related Crime Convictions (n = 2 States)	
States restricting firearm possession by persons convicted of other alcohol-related crimes (such as drunk driving)	Arkansas, Pennsylvania

[a] Source: Carr et al. (22).

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with the possession of firearms, the ownership of firearms, and the use of firearm as a suicide means, and that the association was stronger for heavy alcohol use. Despite this important body of research, more controlled risk factor and intervention studies are needed to better elucidate the relationship between alcohol consumption and firearm use/misuse, very importantly including randomized controlled trials, of which only 1 was identified.

Although analogous to drunk driving that has received ample study, "drunk firing" remains largely unstudied and misunderstood physiologically and mechanistically. The 1 randomized trial found in this review, although small, began to contribute to this gap in knowledge. This trial was in line with other experimental human performance trials, such as driving after alcohol consumption (28, 29) and firearm usage after exposure to substances and conditions other than alcohol (30–42). More trials like this one could further uncover important mechanisms by which shoot-no shoot decisions are made and inform policies that prohibit firearm possession above proscribed levels of alcohol consumption, in much the same way as we do for drunk driving. A further, related trial consideration could also test the relationship between the "day-after" hangover effects of alcohol and subsequent firearm use, as has been done in other human performance trials not involving firearms (12, 43).

Studies of the alcohol sales outlets and firearm violence were similarly small in number. Although numerous studies have addressed the relationship between alcohol outlets and violence more broadly, only 3 studies specifically reported on the relationship between alcohol outlets and firearm violence, and only 1 study among the 3 demonstrated that off-premise outlets were significantly associated with increased odds of firearm assault. This study also included first-hand field observations of patrons and activity in randomly selected alcohol outlets during peak nighttime operations. The high odds ratio generated by off-premise outlets may be the result of the sale and nearby street consumption of high-quantity, high-alcohol content beverages, as well as an often small number of servers who work from behind fortified walls of bulletproof glass and only briefly interact with patrons, mostly to distribute alcohol. Off-premise outlets thus attract heavy drinkers and other at-risk patrons who have come to drink and engage in illegal activities such as gang violence and drug dealing in this poorly monitored street environment (3, 44, 45). Although emerging from a statis-tically significant finding in a single case-control study, strate-gies to address the alcohol sales environment, such as server training, rezoning, and/or enhanced policing in areas with highly clustered off-premise alcohol outlets, are potentially promising gun violence reduction strategies in need of further testing.

The 1 study of the intersection of alcohol and firearm laws and other commentaries raised the possibility of important legal interventions that might now be tested as part of an expanded scientific program to determine if alcohol laws are as-sociated with firearm violence. Laws that specify proscribed blood alcohol levels of intoxication to restrict firearm carry-ing and use, equivalent to those specified nationally for drunk driving, could be valuable prevention strategies. Such laws could reduce alcohol-related firearm injury via the discovery and enhanced punishment of gun carriers who are intoxicated before, and after, they discharge their weapons. In addition, there may be value to testing multiple prior drunk driving convictions as a straightforward and defensible statutory criterion for disqualifying persons from the purchase or possession of firearms (21). Also, explicitly and clearly defining ambiguous terms like "intoxication" and "habitual" in state alcohol and firearm laws, and consistently implementing strict penalties for violations of such laws could be tested as solutions to alcohol-related firearm injury (22).

This systematic review with meta-analysis is not free from limitations. One limitation is our inclusion of only peer-reviewed studies with no inclusion of "gray" literature such as government reports, unpublished studies, and other publications. Excluding the gray literature might introduce publication bias to the current study's summary results given that only statistically significant results tend to be published. Despite that adding gray literature may in and of itself introduce other biases, it is worthy of consideration in future systematic reviews and meta-analyses on this topic.

The current study's synthesis of the existing evidence base on alcohol and firearm violence has identified important gaps in knowledge for future study. Although lacking in certain aspects and in need of further contributions, the consistent and statistically significant findings within this evidence base suggest that alcohol use and firearm violence are strongly interrelated and that alcohol might be focused on as a modifiable risk factor in preventing firearm violence. A noteworthy omission in this evidence base is that no actual public health interventions in the alcohol-firearms relationship have been formally studied, and future research should focus on such interventions by using randomized controlled trials or natural experiments. In this way, policies such as rezoning off-premise alcohol outlets, proscribing blood alcohol levels and enhancing penalties for carrying or using firearms while intoxicated, and considering prior drunk driving convictions as a more precise criterion for disqualifying persons from the purchase or possession of firearms deserve further study if they are to be considered as potential interventions to reduce firearm violence.

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